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EVALUATION OF PRESENTLY-GROWN SUNFLOWER HYBRIDS FOR BIRD-RESISTANCE TRAITS

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As sunflower is an attractive crop for growers in the upper Midwest and Great Plains regions, depredation by birds, particularly blackbirds, continues to be a problem. Many control measures have been proposed to help alleviate this problem (Linz and Hanzel, 1994), but they have yielded limited success. Among the methods considered has been the development of sunflower hybrids possessing characteristics that make them resistant or less attractive to predation by birds.

A number of traits have been implicated as important in affecting the degree of bird damage suffered by sunflower hybrids. These include: i) maturity traits such as time to flowering and maturity (Parfitt and Fox, 1986) and the stay green characteristic (personal observation, J. Hanzel), ii) whole plant traits such as height, stem angle, head angle and head-to-stem distance (Seiler and Rogers, 1987; Parfitt, 1984; Posey et al., 1982), iii) head traits such as diameter, shape, involucral bract length and chaff length (Seiler and Rogers, 1987; Parfitt, 1984; Deodikar et al., 1978), and iv) achene traits such as size, color, chemical composition, hull content and oil content (Mason et al., 1991; Fox and Linz, 1983; Harada, 1977). No study has offered conclusive results. Mason et al. (1991) suggested a two-point plan for future consideration: i) in the short term, existing sunflower hybrids should be evaluated for resistance/susceptibility to bird depredation and degree of damage related to plant characteristics, and ii) in the long term, the correlations between bird damage and plant phenotype would be used as a guide by plant breeders in the development of new bird-resistant varieties. The objective of our study was to address these suggestions.

MATERIALS AND METHODS

Seventy-six entries from the USDA-ARS oilseed sunflower hybrid trial were evaluated in the experiment. Additionally, four genotypes used as susceptible checks by the Bird Resistant Sunflower project at North Dakota State University (NDSU), USDA 894, Seed Tec 330, Seed Tec Sunwheat and Cargill 207, and BRS1, a bird-resistant synthetic released by NDSU, were included for a total of 81 entries. Field experiments were conducted at Sandusky, OH and Alice and Buffalo, ND in 1995. Planting dates were 5 June at Buffalo, 9 June at Alice, and 13 June at Sandusky. Experimental plots consisted of two rows 6.1 m in length spaced 0.76 m apart. They were over-planted, then thinned by hand to a final population of $\approx$ 50,000 plants ha^{-1}. Chemical weed control consisted of preplant incorporation of trifluralin supplemented by hand weeding when necessary.

Agronomic, quality and bird-resistance traits were measured in each plot. Data for the following traits were collected on a plot basis:

Days to flowering. Days from planting to 50% of plants at growth stage R5.5 (Schneiter and Miller, 1981)

Plant height. Length in cm from the soil surface to the point of attachment of the head measured at the R9 stage.

Bird damage. Measure of the area of the heads damaged as percentage of total area taken at the R9 stage (Dolbeer, 1975).

Four plants were randomly chosen in each plot and heads of two of the plants were bagged at the R4 stage to prevent bird depredation. The following data were collected on each of the four plants/plot at the R7 stage:

Head-to-stem distance. Measure of the length between the stem and the closest point on the outer rim of the head in cm.

Head position. Measure of the angle of the head in relation to the soil surface: a head that faced up = 0°; a head that was perpendicular = 90°; and a head that faced down = 180°.

Head shape. Measure of the ratio of the greatest distance across the back of the head to the greatest distance across the front of the head. A concave head had a value > 1, whereas a convex head had a value < 1.

The two bagged heads from each plot were harvested and the following data will be collected from them:

Hull content. Five random achenes from each head will be weighed. They will be dehulled and the hulls weighed. Hull content will be calculated as a percentage of hull weight to achene weight. An average of the five achenes from each head will be used as a plant value for analysis.

Oil content. Will be measured as percentage using a nuclear magnetic resonance (NMR) analyzer.

Experimental design at all locations was a randomized complete block design with four replications. Data were analyzed as a mixed model using standard analysis of variance procedures, with hybrids being considered fixed and locations considered random. A test for homogeneity of variance was performed and it was determined that experiments at different locations could be combined. Pearson product-moment correlations were calculated among measured traits using hybrid means at individual locations (n = 81).

RESULTS AND DISCUSSION

The wet growing season of 1995 caused several problems in our experiment. Besides leading to the relatively late planting dates, the persistent heavy rains early in the season led to the loss of two of the four replications at Alice. Excessive precipitation at Sandusky prevented the harvesting of intact heads for analysis of achene traits. Additionally, the bird populations near the Alice and Buffalo sites were very small which resulted in the inability to evaluate the sunflower hybrids for bird resistance/susceptibility.

As data was being collected for the bird-resistance traits, head-to-stem distance, head position, and head shape, a considerable amount of variability was noted among the four plants measured within each plot. The results of an analysis of variance of the experimental design with sampling for the data collected at Alice and Buffalo indicated that the magnitude of the sampling error sums of squares was two to four times larger than that of the experimental error sums of squares when they were expressed as a percentage of the total sums of squares (Table 1). One possible explanation for this variability is that sunflower breeders are probably not actively selecting for uniformity in these traits. Thus the inbreds and subsequent hybrids they develop may still be

Table 1. Comparison of the magnitudes of the experimental and sampling error sums of squares for three bird-resistance traits in 81 sunflower hybrids grown at two locations in 1995.

		Trait		
Location	Source	Head-to-stem distance	Head position	Head shape
		----------% of Total SS----------		
Alice	Exp't SS	7	13	12
	Samp SS	31	47	43
Buffalo	Exp't SS	10	23	18
	Samp SS	37	44	53

segregating for genes that are responsible for their expression. Additionally, previous studies have shown that these traits are predominantly controlled by non-additive genetic factors which may lead to unexpected phenotypic expression. (Montgomery and Hanzel, 1995).

When measuring the four plants in each plot for bird-resistance traits, two of the measurements were taken on plants that had been bagged prior to flowering. Since the three traits of interest all involved the plant head, an analysis of variance was performed to determine whether bagging of the heads had an effect on expression of the traits. It was found that the bagging effect was only significant ($P < 0.01$) for head shape measured at Buffalo (Table 2). The bagged heads there had a greater head-shape ratio (distance across back of head/distance across front of head) than the unbagged heads indicating that they were more concave. Caution must be practiced when comparing head shape values from Buffalo to those from other locations.

Table 2. Effect of bagging on the expression of three bird-resistance traits in 81 sunflower hybrids grown at two locations in 1995.

	Trait		
Location	Head-to-stem distance	Head position	Head shape
Alice	NS	NS	NS
Buffalo	NS	NS	**

**Significant at the 0.01 probability level; NS = not significant.

Mean squares from the combined analysis of variance for days to flowering, plant height, and the three bird-resistance traits indicated highly significant location and hybrid effects (Table 3). Effects for the interactions between location and hybrid for the bird-resistance traits were also highly significant, whereas those for days to flowering and plant height were not significant. The significant interaction effect was a result of changes in magnitude of expression of these traits at the different locations and not in a major change of rank among the hybrids.

Table 3. Significance of effects from a combined analysis of variance for agronomic and bird-resistance traits of 81 sunflower hybrids grown at three locations in 1995.

Source	Days to flowering	Plant height	Head-to-stem distance	Head position	Head shape
Location(L)	**	**	**	**	**
Hybrid(H)	**	**	**	**	**
L x H	NS	NS	**	**	**

**Significant at the 0.01 probability level; NS = not significant.

Mean squares from the analysis of variance for individual locations indicated significant differences among hybrids for all traits. Means and ranges for days to flowering and head shape were similar at all three locations, whereas those of plant height, head-to-stem

distance, and head shape varied to a great extent among them (Table 4). The large discrepancy between the mean and range for head-to-stem distance at Sandusky and those from Alice and Buffalo may have resulted from differences in measuring techniques between the two sets of observers. Bird damage estimates at Sandusky varied between 0 and 81%, which is a range that is conducive to make well-founded inferences concerning the resistance/susceptibility of the hybrids to bird predation.

Table 4. Mean values and ranges for traits measured in the sunflower hybrid trial grown at three locations in 1995.

Location		Days to flower-ing	Plant height	Head-to-stem distance	Head posi-tion	Head shape	Bird dam-age
			cm	cm	°	B/F†	%
Sandusky	Mean	65	147	15.7	179	0.99	27
	Range	55-74	99-183	2.0-31.0	124-189	0.80-1.31	0-81
Alice	Mean	65	163	7.0	161	0.97	---
	Range	60-76	102-185	0-20.5	128-209	0.75-1.24	---
Buffalo	Mean	68	127	6.8	157	1.03	---
	Range	62-80	89-157	1.0-17.6	132-177	0.86-1.28	---

† Greatest distance across back of head/greatest distance across front of head.

Correlation was found between three of the traits measured and degree of bird damage at Sandusky (Table 5). There was a moderate, negative association ($P < 0.01$) between bird damage and days to flowering, plant height, and head position. The correlation between days to flowering and bird damage is in agreement with findings of Parfitt and Fox (1986) who stated that early hybrids tended to suffer more damage than later-flowering ones. The negative correlation between plant height and bird damage is contrary to what would be expected as birds prefer to perch and feed at a level where their field of vision is maximal. However, plant height was positively correlated ($P < 0.05$) with days to flowering, meaning that the taller hybrids tended to flower later than the shorter ones. The correlation between head position and degree of bird damage indicates that downturned or horizontally-oriented heads may be a useful trait to prevent bird depredation. Head-to-stem distance and head position were correlated at all three locations. It may be possible to incorporate both of these traits into sunflower inbreds by selecting for only one of them. The hybrids showing the strongest expression of each of the bird-resistance traits at all three locations were identified and are presented in Table 6. It appears that these traits are already

Table 5. Phenotypic correlation coefficients among agronomic and bird-resistance traits and bird damage in sunflower hybrids grown at Sandusky, OH in 1995 (n = 81).

Trait	Plant height	Head to-stem distance	Head position	Head shape	Bird damage
Days to flowering	0.276*	0.098	0.440**	-0.128	-0.463**
Plant height		-0.211	0.136	-0.125	-0.311**
Head-to-stem distance			0.402**	0.041	-0.004
Head position				0.067	-0.340**
Head shape					-0.126

*, **Significant at the 0.05 and 0.01 probability levels, respectively.

Table 6. Sunflower hybrids showing strongest expression of each of the bird-resistance traits at all three locations in 1995.

Head-to-stem distance	Head position	Head shape
AgriPro X3855	Triumph 546	Seed Tec Sunwheat
Pioneer DO707	Triumph 565	Mycogen 658
Pioneer DO827	Triumph 571	Mycogen Cavalry
Triumph 571	Gold Country 201	Pioneer 6300
Gold Country 101	Seeds 2000 X9589	Triumph 546
Limagrain 952	Asgrow 477	Triumph 565
Asgrow 477	Asgrow 4285	Triumph 571
Kaystar Hysun 354	Dyna-Gro 399	Seeds 2000 X9589
Cargill 187	Cenex/LOL 821	Limagrain 953
Cargill 270	Proseed 107	Dyna-Gro 399
Cargill X3001		Dekalb 3868
Interstate X03147		Dekalb 3881
Proseed 107		Dekalb 3904
USDA 894		Interstate X13242
NDSU BRS1		Proseed BRH
		NDSU BRS1

prevalent in the germplasm of some of the sunflower breeding programs, (e.g., long head-to-stem distance in Pioneer and Cargill hybrids, horizontal head position in Triumph and Asgrow hybrids, and concave-shaped heads in Triumph and Dekalb hybrids. Several hybrids showed strong expression of two of the bird-resistance traits: Asgrow 477 and Proseed 107 had long head-to-stem distance

and horizontally-oriented heads; NDSU BRS1 had long head-to-stem distance and concave-shaped heads; and Triumph hybrids, 546 and 565, Seeds 2000 X9589, and Dyna-Gro 399 had horizontally-oriented heads and concave-shaped heads. One hybrid, Triumph 571, displayed strong expression of all three bird-resistance traits.

Twenty four of the entries in the experiment suffered less than 10% bird damage. Table 7 contains a list of these genotypes and possible explanations for the lack of damage. Most of the hybrids had heads that were horizontally-oriented or nearly so. Based upon

Table 7. Sunflower hybrids with less than 10% damage at Sandusky in 1995 and possible explanations for the lack of damage.

Hybrid	Possible Explanation†
Seed Tec 2110	POS
Seed Tec 2126	POS, late
Seed Tec 2132	POS
Mycogen Cavalry	SHAPE
Pioneer XF443	?
Triumph 565	POS, SHAPE
Triumph 571	HSD, POS, SHAPE
Limagrain 954	POS
Asgrow 477	HSD, POS
Asgrow 3211	POS
Asgrow 4170	POS
Asgrow 4285	POS
Asgrow 4379	POS
Dyna-Gro 399	POS, SHAPE
Cargill 177	POS
Cargill X3001	HSD
Cenex/LOL 745	POS
Cenex/LOL 821	POS
Dekalb 3881	SHAPE
Dekalb 3904	SHAPE
Interstate 5757	POS
Proseed 107	HSD, POS
USDA 894	HSD
NDSU BRS1	HSD, SHAPE, late, (oil)

† POS = horizontally-oriented heads; SHAPE = concave-shaped heads; HSD = long head-to-stem distance.

the correlations calculated (Table 5), head-to-stem distance and head shape cannot be conclusively considered the reasons for the low bird damage suffered by hybrids possessing them in this experiment. However, previous studies have indicated their importance and one may speculate that they may have aided in preventing depredation here.

A repeat of this experiment is planned for 1996. Hopefully, with better growing conditions and strong bird pressure at all locations, more complete results will be obtained.

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